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HIGH VELOCITY PLASMA IN THE TRANSITION REGION OF AU MIC: A STELLAR ANALOG OF SOLAR EXPLOSIVE EVENTS

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ABSTRACT High-resolution GHRS spectra of the dM0e flare star AU Mic show C IV and Si IV line profiles that are unexpectedly broad and can be fit accurately by two Gaussians (one narrow and the other broad). The broad Gaussian components of the AU Mic line profiles resemble closely the C IV profiles observed in solar explosive events in emerging flux regions (EFRs). For AU Mic we estimate that the EFR covers 12% of the stellar surface with a surface flux $F_{1548} = 1.77 \times 10^5 \text{ ergs cm}^{-2} \text{ s}^{-1}$, which is the saturated flux level previously found by Vilhu. We therefore propose that the EFR is the solar analog of the most active component of the transition region of this and presumably other dMe flare stars.

We analyze high-resolution HST spectra of the dM0e flare star AU Microscopii (HD 197481, Gliese 803), the M dwarf star with one of the brightest ultraviolet emission line fluxes (Linsky *et al.* 1982) and the largest apparent X-ray flux observed by *Einstein*. Saar (1993) measured a mean field strength $B = 4.2 \text{ kG}$ covering the fraction $f=0.55$ of the surface of this star.

We observed AU Mic with the moderate resolution G160M grating and large science aperture in two spectral intervals, one including the C IV 1548.2 Å, 1550.8 Å lines and the other including the Si IV 1393.8 Å, 1402.8 Å lines. The data consist of 17 exposures of 164 seconds each for the C IV region and 22 exposures for the Si IV region. The individual exposures show no significant variability in the C IV line flux. The Si IV fluxes did vary, however, with flux enhancements of factors of about 3.6 and 1.8 over the mean nonflare value for readouts #17 and #20, respectively.

The C IV 1548.2 Å line profile (see Fig. 1) shows very broad wings with emission that can be measured reliably out to at least $\pm 200 \text{ km s}^{-1}$ from line center. The other C IV line and the two Si IV lines (excluding the two flares) have similar profiles. Folding the telescope point spread function through the large science aperture produces a symmetric line that extends out to only $\pm 70 \text{ km s}^{-1}$, which is much too narrow to explain the broad wings. Thus, the observed broad line profile is an intrinsic, permanent feature of the stellar C IV line itself, and it cannot be ascribed to a flare event.

We modeled these lines with two unconstrained Gaussians, which we refer to as the narrow (N) and broad (B) components. In the two-Gaussian fitting process, we convolved the sum of the two Gaussians with the instrumental profile

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before testing the fit, so that when the best fit was found, the widths of the two Gaussians would not be contaminated by the instrumental width.

The centroid velocities of all of the Gaussians are similar to the flux-weighted averages $v^N = +0.9 \pm 1.7 \text{ km s}^{-1}$ and $v^B = +6 \pm 6 \text{ km s}^{-1}$. Since the stellar photospheric radial velocity is -2.1 km s^{-1} , both the narrow and broad components are consistent with no significant shift from the photospheric radial velocity. The fluxes of the narrow components are slightly higher than those of the broad components, and the FWHM of the broad components are about six times those of the narrow components. The Gaussian fits to the four lines indicate that the flux-weighted average $\text{FWHM}^N = 29 \pm 7 \text{ km s}^{-1}$ and $\text{FWHM}^B = 174 \pm 10 \text{ km s}^{-1}$. We believe that nonthermal Doppler motions dominate the observed line profiles as the purely thermal widths at a temperature of 100,000 K, where these ions should be most abundant, is 19.6 and 12.8 km s^{-1} for C IV and Si IV, respectively.

In the Sun, the C IV and Si IV lines are formed in a narrow layer or in loops between the cooler chromosphere and the million degree corona. Very broad transition region emission lines are unusual for the Sun, but they are seen in explosive events that occur in emerging flux regions (EFRs) and during flares. Using the HRTS instrument on board *Spacelab 2*, Brueckner *et al.* (1988) found that the broadest C IV profiles occur in those small areas ($1''$ – $4''$) within active regions where new magnetic flux is emerging into the older flux structures. The FWHM of these profiles can be as broad as 200 km s^{-1} . Cook (1991) argues that the explosive events are signatures of microflares that occur continuously where new magnetic flux emerges and opposite polarities annihilate.

Since the FWHM of the broad components of AU Mic's transition region lines agrees well with the FWHM of C IV lines measured in EFRs, we adopt as our working hypothesis that the observed broad component originates above the portion of the stellar surface where new magnetic flux is emerging and that the narrow component is produced above the remainder of the stellar surface where the magnetic field is strong but relatively stable. For AU Mic we estimate that the EFR covers 12% of the stellar surface with a surface flux $F_{1548} = 1.77 \times 10^5 \text{ ergs cm}^{-2} \text{ s}^{-1}$, which is the saturated flux level previously found by Vilhu (1987). We therefore propose that the EFR is the solar analog of the most active component of the transition region of this and presumably other dMe flare stars.

We estimate the total radiative loss in the atmosphere of an EFR between 10^4 to 10^8 K , but excluding emission in the hydrogen lines and continua, by using the empirical relations derived for the Sun by Bruner and McWhirter (1988) and confirmed for dMe stars by Doyle (1989). Using their formula $\log F_{\text{total}} = 3.358 + 1.080 \log F_{1548}$, we find that the total radiative loss per unit surface area for the EFR component of AU Mic is $F_{\text{total}} = 1.1 \times 10^9 \text{ ergs cm}^{-2} \text{ s}^{-1}$. If we now assume that $T_{\text{eff}} = 3600 \text{ K}$ for AU Mic, then $F_{\text{total}}/\sigma T_{\text{eff}}^4 = 0.11$. Thus a significant fraction of the stellar luminosity must be in the form of magnetic energy in the EFR and the magnetic heating processes are very efficient in converting this energy into heat.

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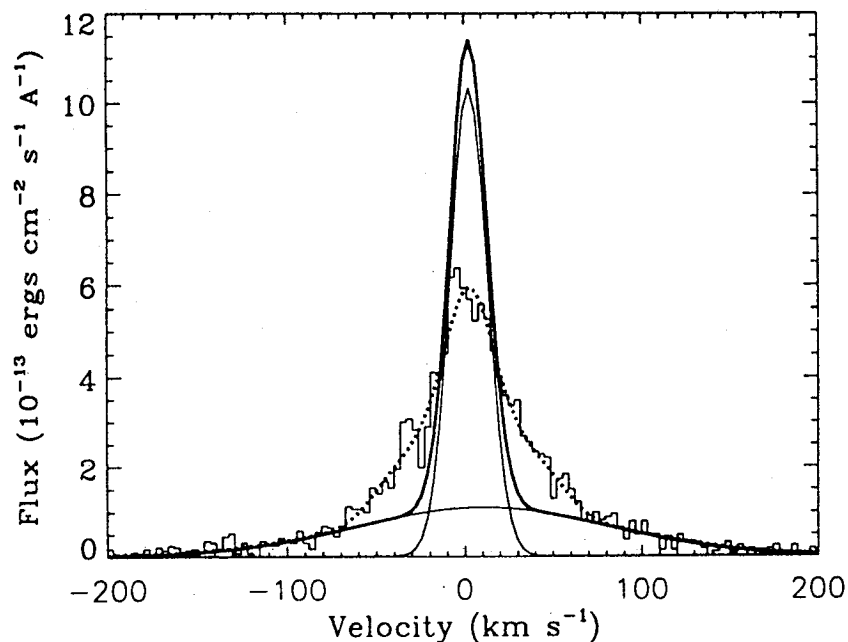


FIGURE I Two-Gaussian fit to the observed C IV 1548.2 Å line. The two Gaussian components and their sum are shown as solid lines. The dotted line is the convolution with the instrumental profile.

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